REMARKS

Status of the Claims

Claims 1-3, 5-11 and 13-17 are now present in this application. Claims 1 and 15 are independent.

By this amendment, claims 1 and 15-17 are amended. No new matter is involved.

Basis for the "an amorphous fluoropolymer" language added to claims 16 is found, for example in the one page article available on the Internet from the manufacturer of CYTOP, a copy of which is attached to this amendment.

Basis for the language "a chemically vapor deposited poly(p-xylene) polymer" is found, from the seven page Wikipedia article, available from the Internet, which explains that Parylene is a trade name for a variety of chemically vapor deposited poly(p-xylene) polymers, a copy of which is attached to this amendment.

Reconsideration of this application, as amended, is respectfully requested.

Entry of Amendments

Applicants respectfully submit that it is proper to enter this amendment because it merely adds the embossing step of claim 4 to both independent claims, and this claimed combination of features has already been searched and examined on its merits. There will be no significant burden on the Examiner to search and examine amended claims 1 and 15, or any of the claims dependent on claims 1 and 15.

Rejection Under 35 U.S.C. § 112, 2nd Paragraph

Claims 16 and 17 stand rejected under 35 U.S.C. § 112, 2nd Paragraph. This rejection is respectfully traversed.

The Examiner has rejected these claims because CYTOP and Parylene are trade names and their scope is uncertain.

In order to overcome this rejection, Applicants have amended claim 16 to provide a generic descriptor with a clear and definite meaning for "CYTOP" and have amended claim 17 to provide a generic descriptor with a clear and definite meaning for "Parylene." Also, the specific terms "CYTOP" and "Parylene" have been deleted from those claims.

Accordingly, reconsideration and withdrawal of this rejection are respectfully requested.

Rejections under 35 U.S.C. § 103

Claims 1-3, 5-11 and 13-17 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over U.S. Patent 6,091,537 to Sun et al. ("Sun") in view of Japanese document 2000-155201 A ("JP '201"). This rejection is respectfully traversed.

A complete discussion of the Examiner's rejection is set forth in the Office Action, and is not being repeated here.

Initially, Applicants respectfully submit that Sun does not disclose the invention recited in claims 1-3, 5-11 and 13-17 for the following reasons:

According to Sun, the hole (cavity) is formed at the beginning of the process. In this regard, reference is made to Sun, col. 3, lines 22-33, which state that Sun first etches its substrate to form cavity 15, which stops at the SiO$_2$ etch stop layer 74. Then a circular hole is formed in the top by etching away region 13 of Si layer 76. It is not until after these steps are accomplished that a photoresist microlens is formed over etched-away region 13 of Si layer 76. Lastly, the comb drive structure of the stage is etched away.

Thus, Sun forms the cavity before forming the lens in an intermediate stage. In other words, Sun does not disclose that the light shaping unit is formed before the forming of a cavity through the micromechanical structure, and fails to disclose that the light shaping unit is made of a polymer. Accordingly, Sun discloses a fabrication method which is reversed from what is recited in the claimed invention in that Sun forms the lens only after it forms the cavity.

The fact that Sun does just the opposite of the claimed invention does not deter the Office Action from concluding that claim 1 is obvious, however. Unfortunately, the reasoning presented in the Office Action in support of this conclusion is unsound.

One reason presented in the rejection to overcome this substantial shortcoming of Sun is that "one of ordinary skill in the art would have found the exact order as obvious dependent on the exact manner in which the step is performed."

However, this reason is not persuasive because, despite the fact that Sun discloses the exact manner in which its etched away cavity 15 is formed, i.e., "from the top" and "using a wet chemical etching solution" and which "would stop at the SiO$_2$ etch stop layer," and despite the fact that Sun discloses the exact manner in which cavity 15 is etched away, Sun still performs the cavity forming step before performing the lens forming step.

The next reason presented to overcome this substantial shortcoming of Sun is that "one of ordinary skill in the art would have found it obvious to have modified the method of Sun et al. by forming the cavity after the formation of the light shaping unit and the supporting structure since the etch stop silicon dioxide layer still exists and would have stopped the etching regardless of when the cavity was formed."

However, this reasoning is not persuasive because if it were followed, then the cavity etchant would obviously ruin the previously formed light shaping unit, resulting in an inoperative device.

Additionally, the Office Action does not present any objective factual evidence in support of these speculative conclusions, but merely presents them as conjecture.

Accordingly, Applicants respectfully submit that the Office Action fails to make out a *prima facie* case of proper motivation to modify Sun, as suggested, as well as otherwise failing to make out a *prima facie* case of obviousness of the claimed invention.

Furthermore, and as discussed in a previous Amendment, Applicants respectfully submit that Sun represents technology that has a more complicated production of its light shaping unit on a micromechanical structure compared with the claimed invention, and includes problems discussed, for example, on page 1, line 39 – page 2, line 3, of Applicants' specification.

This is substantially different than Applicants' claimed invention, where a compact movable structure is produced for a light shaping unit comprising the steps of: forming a light shaping unit from a material provided on a carrier of a first material, and forming a micromechanical structure from the carrier in a second, different material, wherein the forming of the light shaping unit is performed before the forming of the micromechanical structure.

This claimed invention differs from the disclosure of the Sun document, wherein the microlens is preferably Si-based, see column 1, lines 51-53. The micro lens shutter is also Si-based, see column 3, lines 5-7. Thus, the micro lens is fabricated by melting a photo resist pedestal deposited on a silica substrate, see column 3, lines 8-9. Alternatively, the microlens is fabricated by bonding a SiO2 and a SOI wafer, see column 3, line 21.

Thus, the microlens is formed from a Si-based material, as is its micromechanical structure.

According to the present invention however, the lens 12 is formed of a polymer material, which is a different material than the micromechanical structure 14, 16, 18, 22, 28, 29, see page

3, lines 34-42, in the sense that the lens 12 is formed, for example, using a polymer such as e.g. CYTOP or Parylene, while the micromechanical structure 14, 16, 18, 22, 28, 29 is formed out of a silicon layer 44 and a resist layer 42. Sun, on the other hand, does not disclose the use of such different materials for its light shaping unit and for its micromechanical structure.

By using different materials for the light shaping unit 12 and the micromechanical structure 14, 16, 18, 22, 28, 29, these features can be optimised for best performance considering the optical properties and robustness of the mechanics, respectively, as explained, for example on page 7, lines 13-15.

Through the production method according to the invention, where the forming of the light shaping unit 12 in a first material takes place before the forming of the micromechanical structure 14, 16, 18, 22, 28, 29 in a second, different material comprising a cavity, it is possible to form a light shaping unit 12 with an underlying micromechanical structure 14, 16, 18, 22, 28, 29 in a simple way and that does not have any difficult compatibility requirements between forming of micromechanics 14, 16, 18, 22, 28, 29 and forming of light shaping unit 12.

Moreover, by making the lens and the micromechanical structure 14, 16, 18, 22, 28, 29 before making the cavity through the micromechanical structure 14, 16, 18, 22, 28, 29, one avoids weakening the sensitive micromechanical structure 14, 16, 18, 22, 28, 29 during the production. Additionally, expensive later mounting of individual elements in the light shaping unit 12 is also avoided, as explained, for example, on page 7, lines 6-11.

The claimed invention therefore provides a simplified production method of delicate material by firstly producing the lens and then producing the micromechanical structure for moving the lens, and the cavity for letting through the light, which is neither disclosed nor suggested by Sun.

Moreover, Applicants respectfully submit that Sun leads one of ordinary skill in the art away from the claimed invention by stipulating that the microlens and the micromechanical structure is formed <u>after</u> having firstly made a cavity through the carrier, see column 3, lines 26-31. Because Sun's cavity is made before its lens is fabricated, Sun not only does not disclose the claimed invention but, also, cannot possibly render obvious the claimed invention.

Sun also differs from the claimed invention, in that, in the claimed invention the lens and the micromechanical structure are formed while the substrate is strong. By the present production method, the tedious work of placing a separately produced lens inside a fragile, separately

produced micromechanical the structure is omitted. Thus, mass production of light shaping units through embossing is facilitated.

Further, by forming an opening/cavity from the bottom of the carrier in a direction towards the light shaping unit in order to provide a light passage channel, wherein the light shaping unit serves as an etch stop in the forming of the opening, mass production of light shaping units is further simplified and improved.

Claims 8 and 8/9

Moreover, claim 8 recites that the light shaping unit serves as an etch stop in the forming of the opening. This feature is not disclosed by Sun. According to Sun, its microlens is formed using a silicon based material, i.e., the same material as the micromechanical structure and, thus, the Office Action does not explain how the same material can be used as an etch stop. In this regard, Applicants respectfully submit that Sun's microlens is preferably Si- based (see col. 1, lines 51-53), and its microlens shutter is also Si-based (see col. 3, lines 5-7). Therefore, Sun's microlens is fabricated by melting a photoresist pedestal deposited on a silica substrate (see col. 3, lines 8-9). Alternatively, Sun's microlens is fabricated by bonding a SiO2 and a SOI wafer (see col. 3, line 21).

Consequently, Applicants do not understand how Sun's light shaping unit can serve as an etch stop in the forming of the opening, and because of this, Sun is not able to avail itself of further simplification and improvement of the mass production of light shaping units, as is done in Applicants' claimed invention.

Amended Claims 1 and 15

Additionally, the subject matter of claim 4, an embossing feature, has been added to independent claims 1 and 15.

The outstanding Office Action addresses the embossing in the context of its rejection of claim 4, which previously recited that feature, and considered claim 4 to be obvious based on JP '201. However, Applicants respectfully disagree with this conclusion for a number of reasons.

Firstly, JP '201 never discloses that a specific material is used to make its lens. Instead, all that JP '201 discloses in this regard is a "microlens array substrate (?)", as set forth in paragraphs [0012] and [0013], and, in the disclosure in paragraph [0015], of "two sorts of

transparent resin", clearly does not teach a material that is necessarily formed into a lens by an embossing process, as claimed.

Thirdly, Applicants respectfully submit that an embossing of a lens is a rather forceful and violent operation and, because of this, the substrate needs to be as strong as possible in order to reduce the risk of bursting and breaking during the embossing process. However, Sun's lens is clearly formed after its cavity has been formed and Applicants respectfully submit that this results in a structure that clearly would not have as much strength and robustness to withstand lens embossing as would its substrate without the cavity 15 formed therein.

Fourthly, Sun clearly does not disclose using an embossing step to form its lens, instead choosing to use the clearly less forceful and less violent process of resist flow.

Thus, Applicants respectfully submit that because Sun's cavity 15 is formed before its lens is formed, that would teach away from making its lens by embossing.

Additionally, as pointed out in a previous amendment, it is clear from JP '201 that its microlens array does not involve mounting its microlenses on a movable structure, but is simply a passive optical device in which its microlens array lenses are stationary, and do not move.

Thus, JP '201 is not relevant to the claimed invention, which positively recites a compact movable structure of a light shaping unit, and the Office Action does not provide objective evidence that one of ordinary skill in the art would turn to JP '201 to modify Sun's manufacturing process.

Moreover, the Office Action fails to explain why one of ordinary skill in the art would be properly motivated to destroy Sun's fundamentally different method of making its electro-actuated microlens assemblies when neither Sun nor JP '201 contain any hint of doing so. Another way of stating this is that because neither applied reference discloses the claimed method, there is no logical basis on which to conclude that those fundamentally deficient reference disclosures provide the basis for features totally missing from both references.

Accordingly, reconsideration and withdrawal of this rejection are respectfully requested.

Claims 4, 16 and 17

Claims 4, 16 and 17 stand rejected under 35 U.S.C. § 103(a) as being unpatentable over Sun in view of JP '201. This rejection is respectfully traversed as moot with respect to claim 4, which has been canceled and its subject matter included in claims 1 and 15.

The rejection is also traversed on its merits to the extent that it can be considered to apply to amended claims 1 and 15, which contain the embossing step of previously presented claim 4, for reasons presented above.

With respect to claims 16 and 17, Applicants respectfully submit that these claims patentably define over the applied art at least because of the features recited in the independent claims from which they depend, respectively.

Accordingly, reconsideration and withdrawal of the rejection of claims 4 and 16-17 are respectfully requested.

Conclusion

All of the stated grounds of rejection have been properly traversed, accommodated, or rendered moot. Applicants therefore respectfully request that the Examiner reconsider all presently outstanding rejections and that they be withdrawn. It is believed that a full and complete response has been made to the outstanding Office Action, and as such, the present application is in condition for allowance.

In view of the above amendment, Applicants believe the pending application is in condition for allowance.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Robert J. Webster, Registration No. 46472 at the telephone number of the undersigned below to conduct an interview in an effort to expedite prosecution in connection with the present application.

If necessary, the Director is hereby authorized in this, concurrent, and future replies to charge any fees required during the pendency of the above-identified application or credit any overpayment to Deposit Account No. 02-2448.

Dated: April 20, 2011   Respectfully submitted,

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Attachments: Article available on the Internet from the manufacturer of CYTOP (1 page)
               Wikipedia articles explaining CYTOP and Parylene (7 pages)

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CYTOP amorphous fluoropolymer

AGC Chemicals Europe, Ltd. Products

▸ Fluon® PTFE

▸ Fluon® PFA

▸ Fluon® ETFE

▸ Atlas® Fluoroelastomers

▸ Fluon® Colour Concentrates

▸ Fluon® ETFE Film

▸ Asahi Guard

▸ LUMIFLON™

▸ Silica

▸ Solvents

▾ CYTOP

⬥ Technical Information

⬥ Technical Brochure

⬥ Standard of CYTOP

⬥ How to get a "Starter Kit"

⬥ Contact Us

▸ Fine Chemicals

Cytop is an amorphous fluoropolymer

with high optical transparency and excellent chemical, thermal, electrical and surface properties. It has good solubility in certain fluorinated solvents due to its amorphous nature. This, coupled with its thermoplastic characteristics, make it a popular choice as a coating for electronic materials.

The Benefits of CYTOP
The technical properties of Cytop are primarily its transparency, low refractive index low coefficient of optical dispersion and good lamination properties.

Grade Range
The product range of solutions of Cytop fluoropolymer in various solvents (110°C - 180°C), at various concentrations are available on request.

Applications
Electronics Industry: Dielectric coating for semiconductors
Photo Mask Covers
Optical Industry: Anti-reflective coatings

Parylene

From Wikipedia, the free encyclopedia

Parylene is the tradename for a variety of chemical vapor deposited poly(p-xylylene) polymers used as moisture and dielectric barriers. Among them, Parylene C is the most popular due to its combination of barrier properties, cost, and other processing advantages.
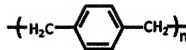
Parylene is green polymer chemistry. It is self-initiated (no initiator needed) and un-terminated (no termination group needed) with no solvent or catalyst required. The commonly used precursor, [2.2] paracyclophane, yields 100% monomer above 550 °C in vacuum[1] and the initiator and does not yield any by-products. That said there are alternative precursors to arrive at the parylene polymers that possess leaving groups as opposed to the cyclophane precursor. The most popular using bromine to yield the parylene AF-4 polymer.[2] However, bromine is corrosive towards most metals and metal alloys and Viton O-rings so it is difficult to work with and precautions are needed.

Parylene C and to a lesser extent AF-4, SF, HT (all the same polymer) are used for coating printed circuit boards (PCBs) and medical devices. There are numerous other applications as parylene is an excellent moisture barrier. It is the most bio-accepted coating for stents, defibrillators, pacemakers and other devices permanently implanted into the body.[3]

Parylenes are relatively soft (0.25 GPa) except for Parylene X (1.0 GPa)[4] and they have poor oxidative resistance (~115 °C) and UV stability,[5] except for Parylene AF-4. However, Parylene AF-4 is more expensive due to a three-step synthesis of its precursor with low yield and a poor deposition efficiency. Their UV stability is so poor that parylene cannot be exposed to regular sunlight without yellowing.

Nearly all the parylenes are insoluble at room temperature except for the alkylated parylenes, one of which is parylene E.[6] This lack of solubility has made it difficult to re-work printed circuit boards coated with parylene.

Copolymers[7] and Nanocomposites (SiO_2/parylene C)[8] of parylene have been deposited at near-room temperature previously; and with strongly electron withdrawing comonomers, parylene can be used as an initiator to initiate polymerizations, such as with N-phenyl maleimide. Using the parylene C/SiO_2 nanocomposites, parylene C could be used as a sacrificial layer to make nanoporous silica thin films with a porosity of >90%.[9]

Contents

Parylene N

Parylene N is a polymer manufactured (chemical vapor deposited) from the *p*-xylylene intermediate. The *p*-xylylene intermediate is commonly derived from [2.2]paracyclophane. The latter compound can be synthesized from *p*-xylene involving several steps involving bromination, amination and Hofmann elmination.[10]

Parylene N is an unsubstituted molecule. Heating [2.2] paracyclophane under low pressure (0.001 − 0.1 Torr) conditions gives rise to the *p*-xylylene intermediate[11][12] which polymerizes when physisorbed on a surface. The *p*-xylylene intermediate has two quantum mechanical states, the benzoid state (triplet state) and the quinoid state (singlet state). The triplet

[2.2] paracyclophane or commonly known as the 'dimer'

state is effectively the initiator and the singlet state is effectively the monomer. The triplet state can be de-activated when in contact with transition metals or metal oxides including Cu/CuO_x.[13][14] Many of the parylenes exhibit this selectivity based on quantum mechanical deactivation of the triplet state, including parylene X. However, like any selective process there is a 'selectivity' window based on mostly deposition pressure and deposition temperature for the paryelne polymers. What is more, the intermediate, *p*-xylylene has a low reactivity and therefore a small 'sticking coefficient' and as a result parylene N produces a highly conformal thin film or coating.
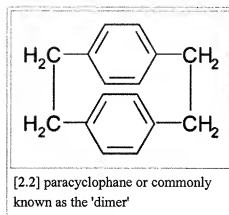
The deposition of parylene N is a function of a two-step process. First, physisorption needs to take place, which is a function of deposition pressure and temperature. The physisorption has inverse Arrhenius kinetics, in other words it is stronger at lower temperatures than higher temperatures. All the parylenes have a critical temperature called the threshold temperature above which practically no deposition is observed. The closer the deposition temperature is to the threshold temperature the weaker the physisorption. Once physisorption occurs than the *p*-xylylene intermediate needs to react with itself (2nd step) for polymerization to occur. For parylene N, its threshold temperature is 40 °C.

Common halogenated parylenes

Parylene N can be derivatived with respect to its main-chain phenyl ring and its aliphatic carbon bonds. The most common parylene is parylene C (one chlorine group per repeat unit, as shown above) followed by parylene D (two chlorine groups per repeat unit); both chlorine groups are on the main-chain phenyl ring. Due to its higher molecular weight parylene C has a higher threshold temperature, 90 °

C, and therefore has a much higher deposition rate, while still possessing a high degree of conformality. It can be deposited at room temperature while still possessing a high degree of conformality and uniformity and a moderate deposition rate >4 microns/hr in a batch process. As a mositure diffusion barrier, the efficacy of coatings scale non-linearly with their density. Halogen atoms such as F, Cl, and Br add much density to the coating and therefore allow the coating to be a better diffusion barrier. In that regard parylene D is a better diffusion barrier compared to parylene C; however, parylene D suffers from poor across-the-chamber uniformity and conformality at room temperature due to its high molecular weight (135 °C threshold temperature), as a result it is used much less than parylene C. There is much concern with the use of chlorine and bromine in materials with RoHS regulation, as a result, a replacement coating for parylene C is desired.
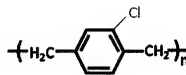
There are a couple of fluorinated parylenes commercially available, parylene AF-4 (generic name, aliphatic flourination 4 atoms) [parylene SF (AF-4, Kisco product), parylene HT (AF-4, SCS product)] and parylene VT-4 (generic name, fluorine atoms on the aromatic ring) [also Parylene CF (VT-4, Kisco product)]. Parylene AF-4 is very expensive due to its inefficient wet chemical synthesis of its precursor and its inefficient deposition due to its low polarizability. Polarizability ultimately determines how strongly the intermediate chemistry interacts with the surface and polarizability strongly correlates with molecular weight of the intermediate except in the case of the fluorinated chemistries. Parylene AF-4 is a PTFE analogue in the sense that its aliphatic chemistry has the repeat unit -CF_2- and as a result has superior oxidative and UV stability. In contrast, parylene VT-4 (sometimes called just parylene F) has the aliphatic -CH_2- chemistry and therefore has poor oxidative and UV stability. Parylene AF-4 has been been used to protect outdoor LED displays and lighting from water, salt and pollutants successfully.
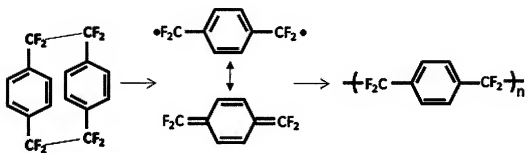

The standard Gorham process[15] regardless of the cyclophane starting chemistry is shown above for parylene AF-4. The octafluoro[2.2]paracyclophane is generally sublimed below <100 °C via different configurations. The cyclophane is transported to a pyrolysis zone where it is 'cracked' to the p-xylylene intermediate. This temperature is generally 700 °C, higher than the temperature (650 °C) used to crack the hydrocarbon cyclophane since the -CF_2-CF_2- bond is stronger than the -CH_2-CH_2- bond. This resonance-stabilized intermediate is transported to a room temperature deposition chamber where polymerization is able to occur under low pressure (1–100 mTorr) conditions. The threshold temperature of parylene AF-4 is very close to room temperature (30–35 °C), as a result, its deposition efficiency is poor.
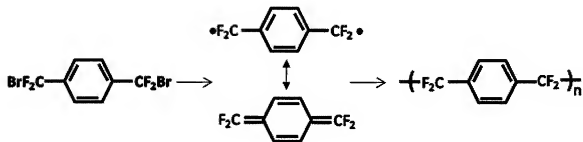
More recently an alternate route to parylene AF-4 was developed as shown above. The advantage to this process is the low cost of synthesis for the precursor. The precursor is also a liquid and can be delivered by standard methods developed in the Semiconductor Industry, such as with a vaporizer or vaporizer with a bubbler. Originally the precursor was just thermally cracked[16] to yield the same intermediate as that produced from the cyclophane; however, with the use of catalysts the 'cracking' temperature can be lowered resulting in less char in the pyrolysis zone and a higher quality polymer thin film.[17][18] By either method free radical bromine is given off as a by-product and is easily converted to hydrogen

bromide, which has to be properly processed or equipment damage will occur.

Reactive parylenes
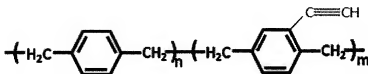
Most parylenes are passivation thin films or coatings. This means they protect the device or part from environmental stresses such as water, chemical attack, or applied field. This is an important property however many applications haves the need to bond other materials to parylene, bond parylene to paryelne, or even immobilize catalysts or enzymes to the parylene surface. Some of the reactive parylenes are parylene A (one amine per repeat unit, Kisco product), parylene AM (one methylene amine group per repeat unit, Kisco product), and parylene X (a reactive hydrocarbon cross-linkable version, not commercially available). Parylene AM is more reactive than A since it is a stronger base. When adjacent to the phenyl ring the amine group, $-NH_2-$, is in resonance stabilization and therefore become more acidic and a result less reactive as a base. However, parylene A is much easier to synthesize and hence it costs less.

Among all the parylenes, parylene X is especially unique since it is: 1) cross-linkable (thermally or with UV-light) 2) Can generate the Cu-acetylide or Ag-acetylide metallorganic intermediates 3) Can undergo 'Click chemistry' 4) Can be used as an adhesive, parylene-to-parylene bonding without any by-products during processing 5) Is amorphous (non-crystalline) and is 6) A hydrocarbon polymer.

Adhesion

The majority of parylene used is deposited as passivation coatings to passivate the part or device towards moisture, chemical attack or as a dielectric insulator. This in turn often means parylene is coated over complex topographies with many different surface chemistries. If one considers a solid-state material, those materials have three fundamental surfaces when exposed to ambient conditions: 1) noble metal surfaces, 2) metal-oxide forming surfaces, and 3) organic surfaces, e.g. polymeric.

Polymeric surfaces generally only possess dispersion forces but may contain functional groups able to bond to adhesion promoters. If parylene is bonded to a printed circuit board (PCB) then often the mechanical tie-points allow parylene to exhibit good adhesion as opposed to bonding through covalent links (chemical bonding). Sometimes plasma methods are effective in the promotion of adhesion between parylene and polymeric surfaces but these techniques are not trivial to employ. The third surface, metal-oxide forming surfaces, generally possess a hydroxyl-terminated surface, M-OH, where M is a metal such as aluminum or chromium. This termination group has the ability to react with commercially available silanes such as A-174 (methacryloxypropyltrimethoxysilane), which is the common adhesion promoter for the parylene polymers.[19]

The A-174 silane can be vapor delivered in situ or bonded via wet chemical baths. In all cases one half of the molecule binds to metal oxide forming surface through sol-gel chemistry (hydrolysis and condensation) and the other half co-polymerizes with parylene via a free radical addition reaction. In all cases the A-174 silane molecule 'lies down' on the surface and forms self-limited molecular layers of less than 1.0 nm. If thick layers are observed than the silane bath has started to 'polymerize' and a new bath should be started. Vapor phase silylation never yields more than a sub-monolayer of silane on the

part being coated; and therefore this problem is circumvented.

History

Parylene development started in 1947, when Michael Szwarc discovered the polymer as one of the thermal decomposition products of a common solvent p-xylene at a temperatures exceeding 1000 °C. Szwarc first postulated the monomer to be para-xylylene which he confirmed by reacting the vapors with iodine and observing the para-xylylene di-iodide as the only product. The reaction yield was only a few percent, and a more efficient route was found later by William F. Gorham at Union Carbide. He deposited parylene films by the thermal decomposition of [2.2] paracyclophane at temperatures exceeding 550 °C and in vacuum below 1 Torr. This process did not require a solvent and resulted in chemically resistant films free from pinholes.[20][21] Since the coating process takes place at ambient temperature in a mild vacuum, and because of parylene's conformal properties, it has a wide variety of applications. Union Carbide commercialized a parylene coating system in 1965. Union Carbide went onto undertake research into the synthesis of numerous parylene precursors, including parylene AF-4, throughout the 1960s into the early 70's. There legacy lived on with NovaTran (now defunct) and now with Specialty Coating Systems. Very little innovation with the parylene polymers has been undertaken since via any of the commercial parylene companies. However, much university research utilizes the unique parylene polymers and their unique deposition process.

Characteristics and advantages

- Hydrophobic, chemically resistant coating with good barrier properties for inorganic and organic media, strong acids, caustic solutions, gases and water vapor
- Low leakage current and a low dielectric constant (average in-plane and out-of-plane: 2.67 parylene N and 2.5 parylene AF-4, SF, HT)[22]
- A biostable, biocompatible coating; FDA approved for various applications
- Dense pinhole free, with thickness above 1.4 nm[23]
- Coating without temperature load of the substrates as coating takes place at ambient temperature in the vacuum
- Highly corrosion resistant
- Completely homogeneous surface
- Oxidatively stable up to 350 °C (Parylene AF-4, SF, HT)
- Low intrinsic thin film stress due to its room temperature deposition
- Low coefficient of friction (AF-4, HT, SF)
- Very low permeability to gases

Typical applications

Parylene films have been used in various applications, including [20]

- Hydrophobic coating (moisture barriers, e.g. for biomedical hoses)
- Barrier layers (e.g. for filter, diaphragms, valves)
- Microwave electronics
- Sensors in rough environment (e.g. automotive fuel/air sensors)
- Electronics for space travel and military
- Corrosion protection for metallic surfaces
- Reinforcement of micro-structures

- Protection of plastic, rubber, etc. from harmful environmental conditions
- Reduction of friction, e.g., for guiding catheters, acupuncture needles and Microelectromechanical systems.

References

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